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The past ten years has been a period of phenomenal growth in the use and development of electronic digital computers. Computer applications-scientific and nonscientific have increased rapidly both in number and in the range of subject matter involved. Computer equipment has become increasingly diverse and new and improved models are continually introduced. Despite these rapid advances, the full impact and the full utilization of this unique tool has yet to be realized.

At this point in the evolution of data processing the Federal Government has emerged as the largest single user of computer equipment. A cross section of computer applications in Federal Government would be almost as varied as a cross section of the Government activities themselves.

Not all positions concerned with the use of digital computers will be classified in the Computer Operation Series, GS-0332, the Computer Specialist Series, GS-0334, the Computer Clerk and Assistant Series, GS-0335, or the Computer Science Series, GS-1550. In many positions the subject matter of the applications clearly reflects the paramount knowledges required for work performance, and computer skills are secondary. This, typically, is the case where computers or computer linked terminals are found in word processing or communications work. Similarly, when computers are used for scientific or mathematical applications, the computer normally is considered a device for the solution of problems in which knowledges of the scientific field or higher mathematics are paramount. Such positions are not normally classified in the computer series. Also, positions that involve responsibility for solving problems using analog computers-which are primarily devices for measuring, testing, and computing certain scientific and mathematical problems -- are excluded from these series.

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DATA PROCESSING IN GOVERNMENT

A key characteristic of the computer field in Government is diversity-diversity in equipment, in applications, and diversity in the way agencies and activities have organized to accomplish work through the use of computers. A second, but no less important, characteristic of the field is change.

Computers have brought with them new concepts of how work can be accomplished. Initially, computers were looked upon as devices to mechanize existing work processes and functions. However, computer personnel have become more skilled, and they are now more frequently devising new systems in which work processes and functions are combined, merged, or developed in new ways, in an overall effort to obtain maximum use of computer capabilities. These new systems and computer uses have in turn generated changes in a number of the concepts of work organization principles and methods themselves.

The growth and changes in the use of computer concepts have affected both the character and the scope of individual computer applications in Government. Computers are increasingly viewed as tools for decisionmaking by managers and subject matter specialists. Consequently, a growing number of computer applications are concerned with decisionmaking processes in addition to recordkeeping and reporting processes.

Many data processing applications continue to be tailored to the specific requirements of one or more distinct functions at a specific activity. But increasing numbers of applications are being developed as comprehensive systems which integrate many functions previously considered separate and distinct.

In addition, many agencies, bureaus, and like activities have developed standard data processing systems to be used at subordinate activities involved in similar functions. These facilitate the operation of large integrated systems in which data can be readily communicated among activities at locations throughout the country. At (()) various organizational levels, library collections of computer routines and subroutines exist and are used as resources in developing computer programs which contain sequences (computations indexing procedures, etc.) which are similar enough to warrant like treatment. Library routines or subroutines can be used directly by substituting data elements in new problems, or the routines may be modified to provide for additional factors not included in the preformulated routines.

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It is not possible to forecast changes in the character and scope of computer applications. However, the possibilities of developing common programs for general administrative functions which many agencies could use are now being discussed, and may be a forerunner of increasing standardization of this field. The growing development of data bases and standard data elements for use throughout agencies and bureaus may also alter the nature of functions required at individual activities. At the same time, the need for safeguarding classified data and protecting the privacy of certain data has imposed new security requirements on the design of systems.

The full impact of the emergence of the field of teleprocessing and computer graphics cannot yet be predicted. The ever increasing use of networks of computers undoubtedly will give further impetus to the development of real-time and time-sharing systems.

Changes in the design of equipment have been instrumental in bringing about some of the significant changes in computer use and techniques discussed above. A new generation of equipment has largely replaced the computers which were in use ten years ago. An extremely wide range of makes and models of computers with considerable differences in machine capabilities and characteristics has emerged. In addition, a number of computer design features are now incorporated in a growing variety of special-purpose office machines or computer related equipment.

UNDERSTANDING DIGITAL COMPUTERS

One cannot appreciate the nature of computer methods and work processes on the basis of observation alone. Essential to an understanding of the data processing occupations is the recognition that' computers do not produce work and solve problems as humans do.

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As human beings, we are not conscious of each motion involved in such everyday actions as walking or eating which we have learned to perform and we are not aware of each step we take in solving problems, or in performing arithmetic calculations. We instinctively use shortcuts, change our minds, discard, or eliminate facts without being conscious of the individual steps involved.

Computers, on the other hand, can accept problems only when the problems are stated in the basic elements of information or data required for solution. They can perform logical comparisons, make decisions, and carry out complex calculations only when the steps involved are reduced to those underlying elements which are assumed rather than expressed in everyday human statements and solutions of problems. Thus, subject matter actions and work processes must be analyzed and expressed in terms of the movement of data between the various internal components of the computer. Programming instructions must be related to the functions which computers perform and stated in a form compatible with the limitations of the computer to accept and process data.

As a result of these requirements, data processing specialists are forced to think about problems in terms of a series of steps and units of information which are more detailed than those normally recognized during the human solution of these problems. Problems must be restated and rephrased as a series of decision questions in which all elements can be reduced to two choices. Often, problem solutions are depicted in the form of diagrams or charts which are the visual representations of the alternate actions or sequences of steps required for each of the possible choices in the series of questions.

In order to avoid repeating the complete name or identification of each item of information involved in such decisions, codes in the form of letters and digits are devised and used to represent the actual item of information involved. Consequently, a meaningful re-view of the programs developed and other work products in the field demands a great deal of knowledge both about computer methods and about the specifics of the application involved. Furthermore, a review of the end product may be only faintly suggestive of the actual level of skill and knowledge applied.

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As an additional complication, the need to describe the unique techniques and processes used in computer work has resulted in the emergence of a considerable body of special terminology. An understanding of these terms is essential to anyone hoping to understand the field. The Federal Information Processing Standard 11-1 has been developed and published to standardize their use. Glossaries of terms aligned with this publication are provided in the position classification standards. However, in practice, terms are still not always used in a precise or consistent fashion.

COMPUTER CHARACTERISTICS

Very generally, digital computers are distinguished by the speed with which they accept input data and produce output data, by their capacity to store instructions and data internally in memory, and by their ability to rapidly manipulate data internally in accordance with the stored program instructions. Two broad types of digital computers in use today can be characterized as general purpose computers and special purpose computers.

Most computers used in conventional data processing work are of the general purpose type. They can be used to accomplish a variety of subject matter applications. Included are computers with a particular architecture such as parallel processors, a specific configuration such as those with remotely located terminals, or various operating modes such as time-shared or batch. Their computing capabilities may range from tens of millions of instructions per second as in current supercomputers, to thousands of instructions per second as in certain minicomputers. Similarly, the available storage capacity ranges from billions of characters to a few thousand. The capabilities of a general purpose computer are described by factors such as the computing speed of the processor, the capacity and access time of its primary and secondary storage units, the data transfer rates of the input-output devices, and cost.

Special purpose computers are designed for a narrow range of applications. Some special purpose computers are not distinguishable from general purpose computers on the basis of physical characteristics. However, many special purpose computers are used under conditions which may require that the computers withstand vibrations, nuclear radiation, unstable power source, or other hostile environments. Operational conditions may necessitate minimum maintenance, unattended operation for prolonged periods of time, or a requirement for degradation in capability rather than total failure. Some of these computers have been designed to automate certain laboratory operations or provide for process control in chemical manufacturing. One large category of special purpose computers are those of the "embedded" variety, i. e., computers designed as an integral part of an electromechanical system such as an aircraft guidance system.

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For all their speed and efficiency, computers are unable to think creatively as we do. The term "electronic brain" is a misnomer. Rather, computers can be likened to superefficient robots lacking in imagination. They do exactly what they are told to do and no more. If during execution of any step in the program it is found to be incomplete, incorrect, or a data situation arises that is not precisely, covered by instructions, the computer will come to a halt and move on to the next program. Worse yet, it may start grinding out nonsense at electronic speeds; for instance, data may be misinterpreted as instructions.

As a result, computer personnel typically serve as intermediaries between the machines and their customers. In a sense, the personnel think for the computer by. anticipating and providing instructions used by the machines for all actions required, and for all contingencies which may arise. Grossly oversimplified, a sequence of these machine instructions for an inventory updating operations might run as follows:

Go to address A containing previous balance of Stock Item No. 1234. Read the information contained there. Write it in the arithmetic unit. Go to the tape which lists issuances. Find Stock Item No. 1234. Read the figure there. Take it to the arithmetic unit. Subtract it from the old balance. Hold the result (new balance) in the arithmetic unit. Go to address B, containing the reorder point figure for item 1234. Compare this figure with the new balance for item 1234 in the arithmetic unit. If the balance is equal to or less than the reorder point, write an instruction to reorder on a separate tape. When finished with that, or if the new balance is above the reorder point, put the reorder point number back in address B. Put the new balance of Stock Item No. 1234 back in address A. Go on to the next step.

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Instructions of this kind must, of course, be translated to a language (code) which the machine can use. As a further complication computers can record and work with bits of information only in terms of a plus (electrical charge) or zero (no electrical charge). Computers work internally with some form of the binary code, as they cannot accommodate decimal numbers. However, techniques now permit programmers to code in decimal form, and the machines make the translation.

As a result of the many levels of programming languages available today, few programmers write instructions in the precise format which the machines can accept directly. Normally, instructions are written in symbolic or mnemonic (memory aided near-words) form and are generally called source programs. Source programs are then converted into object programs by compilers or assemblers, which are special- purpose programs that are part of the system software usually developed by the manufacturer. These special-purpose programs translate the symbols and words into the actual binary instructions which the computers will accept and, in the case of compilers, into the series of the specific steps required. There are a variety of kinds and levels of programming languages, including one developed for business procedures, scientific problems, interactive situations, report generation, and many other applications.

The very speeds possible for internal operation of computers have posed problems of data input and output. Computers can process data faster than it can be printed out. Thus, a variety of units of, auxiliary or peripheral equipment typically are used in addition to the central processing unit. Peripheral equipment is used to change data from punched cards to magnetic media and to change it again when output is desired. Cards may be used as direct input or data may be introduced to the memory unit from communications net-works. High- speed printers often are used to print the results of computer operations. Frequently, they are connected to a small separate computer with the obvious advantage that the efficiency of the larger, more costly equipment is not slowed by the speed of its, input and output devices. In some cases computers are linked together in a master/slave relationship, or a single computer may be made to switch work between several programs in order to maximize use of data storage facilities and input/output devices.

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TYPICAL DATA PROCESSING ACTIVITIES AND ASSIGNMENTS

Certain basic decisions and essential activities are necessary to accomplish work through the use of computers. It must first be determined that there is a need to automate an operation in question, and that the use of a computer is both a feasible and economical method of accomplishing the work. Computer equipment must be selected or otherwise be provided or made available. Systems must be devised to identify and generate the subject matter data necessary to produce the work products, and to insure the continued collection 'and presentation of such data in an orderly and systematic fashion. Programs muse he developed so that the machines themselves can be instructed. Data must be input to the computer in the form of tape, cards, or other media, and the computers must be set in operation to produce the variety of documents, listings, control signals, or other work required. In addition, the effective operation of ongoing data processing systems usually requires a variety of scheduling, control, and related activities to insure that resources are utilized in the most efficient manner possible.

There is no "best" way by which computer work can be accomplished. Each agency and activity tailors its method of operation and assignment of tasks to fit its own needs and objectives. As a result, the activities discussed above and their associated tasks may be found in any number of combinations in the individual assignments made to computer personnel. For example, in some organizations the responsibility for the design of systems takes highly specialized forms with the result that individuals concentrate on particular aspects of systems analysis (e. g., the design of basic codes or data elements). In other organizations individuals may be responsible for all systems analysis and program development tasks for a total application from its inception to the completion of a finished program ready to run on a machine.

Subject matter personnel, too, play varying roles in automating their operations. In some organizations subject matter personnel are restricted to contributing facts about the work processes accomplished (()) and criteria used. In other situations they may serve as team leaders charged with the overall responsibility for automating the work process in their subject matter areas. In the latter circumstances computer personnel serve as advisers regarding the use of computer methods or techniques.

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Changes in the operating systems of internal programs which govern computer operations have influenced the way the work is organized. Interactive features of the system software have allowed greater involvement by subject matter users in activities previously considered within the province of computer specialist work. The changes in the operating systems also have had an effect on the division of labor within the computer organization. For example, in 1965 the role of the computer operator typically was that of a surrogate for the programmer in running a job on the computer. The operator loaded the programs and data, activated the machinery, and, if problems occurred, generally attempted to respond in the way the programmer would respond if the programmer were present. In contrast, a typical 1980 environment may be characterized as one in which a highly complex operating system dominates and controls operation of the computer. The programmer or subject matter user is in direct communication with the operating system via a terminal. The programs, data, and job control instructions are stored permanently in the computer. The operating system schedules and executes jobs as established by designated priority or changed through the terminal. Notices of error conditions appear at the terminal, and the programmer or subject matter user responds to them in a kind of conversation between human and computer.

The extraordinary size and complexity of many modern computer applications have led to an increased emphasis on systematizing the development process for new applications. The goal is to avoid duplication of effort and facilitate later changes. The following is a sample of approaches frequently employed towards these ends:

-Top-down design and development. In this design technique, a problem is attacked from the most general level (the top) to the most specific.

-Functional isolation. This technique places similar program functions together in adjacent modules and assures that identical functions are performed in the same module. The purpose is to simplify finding program errors and locatiOns of modifications by just identifying the functions involved.

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-Structured programming. This addresses the internal organization of an individual program module. Certain rules are applied to programming which ensures each module and each component part of it have only one entrance and one exit and that only certain basic coding structures are used. The module generally is limited in size, e.g., no more than 100 lines of code.

-The structured walk-through. This is a technique used to verify the logic of each module as it is developed. The developer of a module explains the step-by-step logic to at least one other programmer familiar with the project. This ensures that the expected goals, logic, and module specifications have been understood by another member of the team, who in turn serves as back-up during development and as a cross-check for the developer.

Some of the techniques, such as the structured walk-through, are particularly suited to work done by teams. Experimentation continues with different forms of data processing team organization. For example, at the time of this writing one of the more popular ideas is that of the chief programmer/team concept. This is a small group of individuals each of whom has a specific role in the development of a portion of a data processing system. In ideal form the group consists of three to five people:

a. A technical leader responsible for the product's design and the technical direction of the people on the team. This role includes obtaining information from the user about requirements and briefing the user and higher management on the technical aspects of the project. This individual personally programs the more difficult parts of the system. He or she ensures that the correct linkages with related components of the system are maintained and provides technical guidance to other team members.

b. An administrative worker who carries out supportive tasks for the team. There may be several teams for which he or she is responsible. This individual does not make technical assignments.

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He or she monitors overall progress, coordinates leave and over-time, arranges for meetings with-higher management, and accomplishes, with appropriate consultation, the bulk of the administrative paperwork.

c. One or more technical workers. These individuals perform the analysis, testing, documentation, and implementation tasks assigned by the technical leader. The senior individual in this group serves as an assistant to the technical leader. He or she is knowledgeable about the overall project for which the team is responsible and hence is able to act for the technical leader if that employee is unavailable.

d. An assistant responsible for maintaining a complete record of the individual modules developed by the other members of the team. He or she may test run integrated versions of the system. Typically, the primary duty of this employee is to maintain the system documentation.

In summary, the evolution of computer technology and associated variations in work methods, organization and staffing patterns will sometimes pose problems in determining which of the several series or specializations identified with computer work is appropriately used to classify an individual position. Problems may also exist in determining whether a position should be classified in any of the computer series, or whether the series identified with the subject matter to be automated does not, in fact, more appropriately reflect the paramount knowledges and skills required. Since the activities identified with each of the computer series are discussed in considerable detail in the classification standards for the GS-332/334/ 335 series and the

Computer Science Series, GS-1550, specific problems in the use of series and specializations are not explored here. Typically, these and related problems can be resolved by review of the occupational material for the individual series with particular attention to the "inclusions" and "exclusions" provided.

ENDNOTE

This material should be filed in front of the position classification standard for the Computer Operation Series, GS-0332. This material supersedes the material under the heading "Background Information Regarding Computer Occupations", GS-0330/0335, issued in October 1965.